4

Distance Process Monitoring using LabVIEW Environment

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1. Introduction

Technological process supervision assumes acquisition, processing and returning the commands for a big number of parameters. At the same time, it is necessary to monitor the investigated parameters, because the history is needed in guaranteeing the performances, but also establishing the causes which lead to malfunctions.
Communication technologies and we refer here to Internet, which is mainly spread, allow data, acquired from long distances, to be concentrated in high performance servers. In the same time, following the temporal evolution of acquired parameters can be done from any computer, connected to Internet. This issue is suited both in technological processes, but also in education process, where a laboratory with high performance acquisition equipments and an Internet connection can be used by other laboratories less equipped. We have focused on a solution of data acquisition/distribution, using Lab VIEW framework, designated for remote process control and long distance learning.
The chapter is organised as follows: Section 2 presents arguments in favor of remote data aquisition and ways it can benefit the industrial operator. Section 3 shows our general view on such a system and a laboratory implementation of a simulation environment. Section 4 is dedicated to the client applications, each running on a dedicated network-connected workstation. Section 5 describes the main server application, the communication technologies we have used and an analysis of network performance in the current scenario. Section 6 presents the conclusion we can draw from our work, further developments and improvements.

2. Why remote data aquisition?

In many of industrial processes, the control at a distance of the equipments based on the received parameters is preferred. Sometimes, this process is absolutely necessary because of some high risk elements, or because of the conditions that do not allow the user to access it. As an example, one can mention the atomic piles where because of the high degree of radiations, the watch and control of the parameters must be done at a distance. Another example can be the watch of the furnaces, especially in the foundry works where because of the high temperatures, the user cannot physically stay in those areas.
More than this, an advantage of the watch/ control at a distance is the possibility to watch more over than one equipment with a single acquisition server. This aspect allows the

taking over of the data from more sensors connected to various industrial equipments and also the transmission of the controls to them. The process can be developed from more than one host in the same time. Thus, there can be a client host that commands through Internet the parameters modification of an installation, relying on a pressure sensor, while another client modifies the working characteristics of a thermal system, both sensors being connected to the same server. To sum up, one can say that the advantages of control at a distance of the industrial equipment, relying on the watch/control of the parameters are:

- people should not have to work in the risk areas;
- the possibility to control more than one equipment in the same time from different hosts;
- the possibility to watch from a larger number of stations, without extra investments.. It should be mentioned that the control of a sensor can be done by a single terminal, while the watch can be developed from many such terminals;
- the possibility of making some statistics in real time of the functioning of the equipment. This can be done even by the management department of a company.

3. Distributed system architecture

This section describes the distributed system, set up in an laboratory environment. It includes the following components:

- 3 workstations: PCs running Windows XP Professional SP3 and different versions of LabVIEW (higher than 8.2). Common hardware configuration Pentium 4 processor 3.06 GHz, 512MB RAM, 80GB HDD.
- 1 workstation acting as application server: PC running Windows XP Professional SP3 and LabVIEW 2009. Superior hardware configuration Pentium DualCore processor, 2GB RAM, 250GB HDD.
- network infrastructure: network server, routers, ethernet cables;
- always-on internet connection: required by the application server to share information with the outside world.

A diagram of the proposed system is shown in Figure 1.

In order to prove the feasability of the distance monitoring application, we have used multiple processes - developed in LabVIEW and running on the corresponding workstations. For this chapter, three applications have been chosen:

- **Temperature Monitoring and Control**: based on the plug-in data aquisition board NI PCI-6014E (produced by National Instruments), which focuses both on the continous aquisition of analog temeperature samples and on the generation of digital commands for a heating element with the possibility of dynamic adjusting of the temperature limits (lower and upper limit) for the desired operation of the system;
- **Acquisition/Generation of Digital Signals**: based on the plug-in KPCI-3102 (produced by Keithley) board which targets mainly the acquisition of digital signals and the generation of numeric commands to the exterior;
- **Environmental Monitoring throughWireless Sensor Networks**: based on IRIS 2,4GHz wireless sensor nodes (produced by Memsic Inc.) forming a self-organizing, self-healing wireless mesh network and a MIB520 USB gateway as a data sink. The gateway is then connected with LabVIEW thorugh appropiate drivers and the environment data (temperature, humidity, pressure, light, acceleration) is passed on to the server for processing, analyisis and storage.

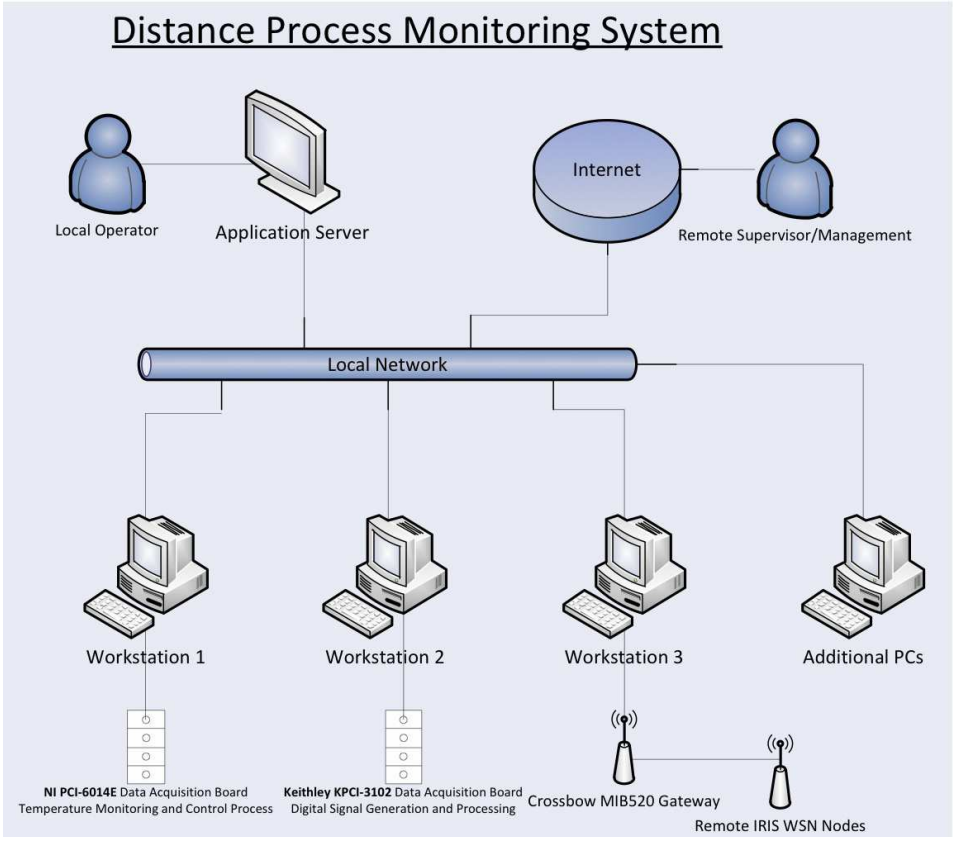

Fig. 1. Proposed Diagram of the Distributed System

For the chosen applications, the data acquisition boards/serial gateway represent the core of the local hardware system. The selection of hardware components was made in order to demonstrate the good integration with LabVIEW and the remote communication in the local network or Internet even if we are dealing with products from different manufacturers.
The principle scheme of the NI PCI-6014E is shown in Figure 2 and we then make short comments on the different blocks:

- **I/O Connector**: the connector to which the inputs and outputs from real world are brought up; the connector is prolonged through a ribbon cable next to a connection board where, through screw terminals, electrical links with real world are made;
- **Analog Input**: analogical inputs block; its components are: the analogical multiplexer MUX, the instrumental amplifier NI-PGIA with programmable amplification factor, the numerical-analogical converter ADC, the temporary memory for numerical equivalents of input signals AI FIFO and the trigger modes for input signals Analog Trigger;
- **Analog Output**: the analogical outputs block; its components are: two numerical-analogical converters (DAC0 and DAC1) and a memory (AO FIFO) where the numerical equivalents of analogical output signals are brought, as well as the necessary controls for choosing the working domain and the polarity of the output tension;

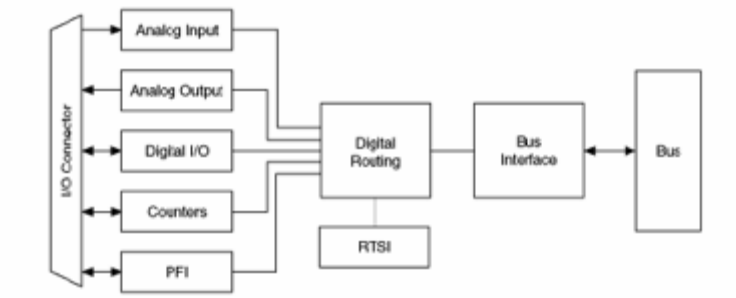

Fig. 2. Principle scheme of National Instruments PCI-6014E

- **Digital I/O**: numerical inputs/outputs block composed of 8 pins for general usage that can be individually configured, through software, as numerical inputs, respective numerical outputs;
- **Counters**: contains two counters of 24 bits, each one having two inputs (Source and Gate), one output (Out) and two software registers capable of different operations;
- **PFI (Programmable Function Interface)**: contains 10 connections with the outside of the board through which one can collect temporary signals from outside and can generate different kinds of internal board signals, inclusively the signals in relation with the operation mod for the two counters of 24 bits;
- **Digital Routing**: contains all the circuits which manage the data flow between PCs pipe-line and the acquisition subsystems (analog and digital inputs/outputs, counters). The numeric routing circuits use FIFO memory in each subsystem to ensure an efficient flow of data. Also, through these circuits pass temporal and control signals which synchronize the acquisition;
- **RTSI (Real-Time System Integration Bus)**: an additional pipe-line through which you can achieve synchronization for specific measuring functions, when there are more than one acquisition board installed on the same PC, making use of the same time events;
- **Bus Interface**: contains the hardware components through which the acquisition board connects to the PCs pipe-line, also it requires a driver which is included with the product.

The multifunction plug-in KPCI-3102 board, produced by Keithley Instruments, has the block diagram described in Figure 3, where:

- **16 Channel Mux**: represents the 16 analog inputs fed into the Gain Amp through an analog multiplexer;
- **ADC**: analog to digital converter which allows for the control of the conversion clock;
- **Tristate Buffers**: tristate memory units with the possibility of selection for the corresponding analog inputs or their digital equivalents on two 8bit ports;
- **1 kSample Input FIFO**: temporary FIFO memory of 1k of memory on each input sample;
- **Bidirectional 8bit Latch**: programmable bidirectional memory units for the digital input/ outputs (DIO), ports A and B;
- **4 User Counter/Timers 16bit each**: four 16bit counter/timers, available to the user;
- **Multiplying DAC**: digital to analog converters with multiplication (two);
- **Trigger Clock Logic; A/D Counter 24bits; TScan Counter 24bits**: logical circuits for external synchronization of the acquired analog channels;

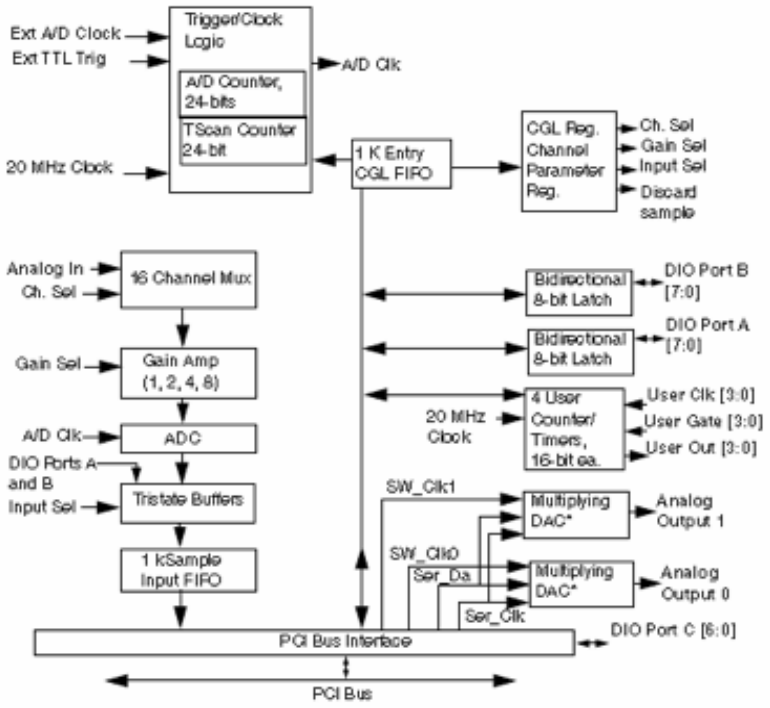

Fig. 3. Block Diagram of the Multifunction Digital Analog I/O Board KPCI-3102

- **CGL Reg., Channel Parameter Reg.**: registries for external configuration;
- **PCI Bus Interface**: connection to the computer PCI Bus.

Connecting the workstation with the installed KPCI-3102 board to the physical process, a wide ribbon cable is used 1:1 and a screw terminal board (see Figure 4).

Fig. 4. Connecting the Data Acquisition Boards through 1:1 Cable to the Screw Terminal

Finally, we use the MIB520CB USB Interface board for USB connectivity to the IRIS wireless sensor network we have deployed throughout the laboratory. This provides communication capabilities as well as in-system programming for the processor/radio boards of the nodes. It is supplied with power via USB bus. Our model CB employs a female connector. The board uses a FTDI FT2232C chip to use USB ports as virtual COM ports which are later used for data acquisition. Therefore the appropiate drivers have to be installed on first use. It will install two COM ports. The lower one is used for mote programming which we will not handle in this paper and the higher number one for data communication via USB. A top view photo of the MIB520CB is shown in Figure 5.

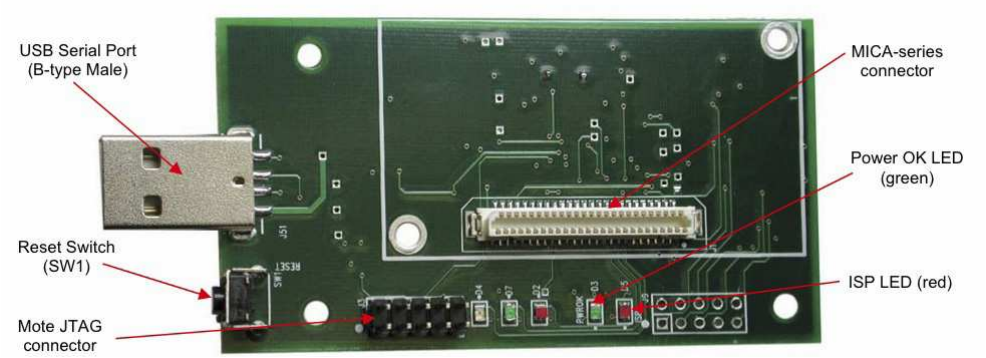

Fig. 5. Photo of top view of an MIB520CB

4. Client applications

4.1 Temperature monitoring and control

Many real applications, often encountered in process automation practice, require maintaining the process variables between certain limits, realising therefore a bipositional control of the investigated parameters. For example, an air conditioning unit for a HVAC application should maintain room temperature around 24°C ± 0.1°C. This means that, during winter, the heater is switched on until the room temperature reaches the upper limit of 24.1°C, turning it off until the temperature reaches the lower limit of 23.9°C and repeating the sequence. This happens also in summer conditions (heat) when the system controls the cooling element of the unit. This simple example can be accompanied by many others such as: keeping the liquid level in a tank between certaing values using level sensors, mantaining the pressure in a container using pressostats, which prove the variety of applications which employ bipositional control. Electronic control units can use signal from analog transducers with unified current output (4mA ÷ 20mA) and there are also models which allow connection directly to the sensitive element for the investigated variable.

The goal of this application is to demonstrate the usefullness of multifunction data acquisition boards for monitoting and bipositional control. This is achieved by using the LabVIEW environment to acquire and process signals, generating commands and displaying the progress of the process variables to the user.

For the monitoring and bipositional temperature control, we employ the laboratory set-up shown in Figure 6:

- Thermostatic Bath: metallic enclosure with lid, thermoresistance Pt100 and water heater, filled with water;
- SA: power supply;
- ATr: Pt100 thermoresistance adapter, calibrated for the 0°C ÷ 100°C range;
- INTr: numeric measured temperature indicator (000 for 0°C to 999 for 100°C);
- Heater control unit (top-right corner): relay block, REED intermediate relay and power relay type RI33, used for controlling the water heater element;
- Connector block: external connection terminal board CB-68LP shipped with the PCI-6014 board;
- C: 220μF capacitor;
- K: single pole switch;

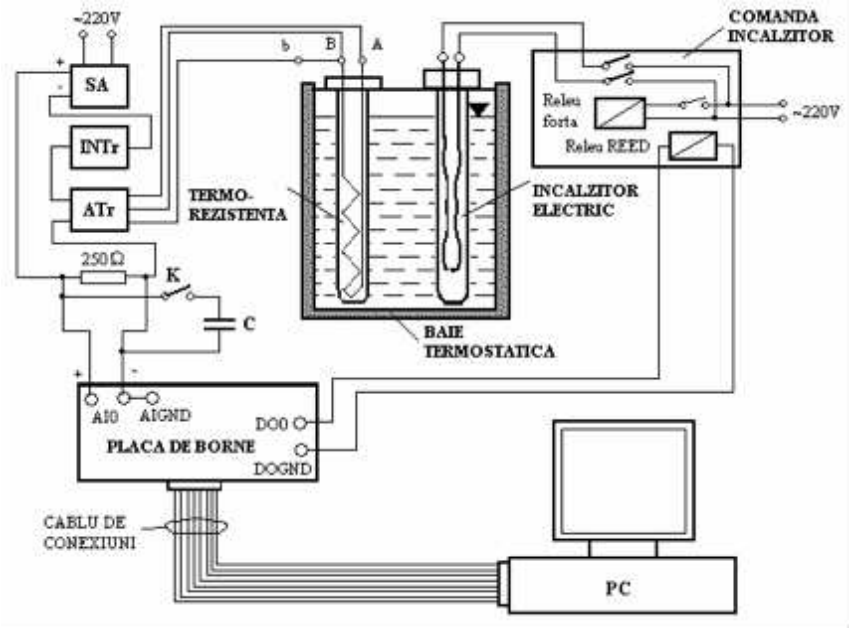

Fig. 6. Laboratory Set-Up for Temperature Monitoring and Control Application using NI PCI- 6014E Board

- PC: personal computer workstation with appropiate data aquisition board drivers for the NI PCI-6014E and software for application development according to the requirements: monitoiring and bipositional control of the temperature in a thermostatic bath by aquiring the analog voltage value on a 250 Ω resistance inserted in the current loop of a temperature transducer with thermoresistance and the numeric control of the electric heater including the analysis of passive filtration (capacitive) and software filtration on the quality of the control system.

Operating within the LabVIEW environment, we first have to install appropiate drivers for the NI PCI-6014E board, following the procedure described by the user manual. This being performed, we go on to the actual programming of the LabVIEW virtual instrument. This application has been initially developed under LabVIEW 6.1 but has been kept up-to-date and the current version is compatible with the LabVIEW 2009 version to accomodate the reader with the benefits brought upon by newer versions of the software.

Figure 7 shows the block diagram and Figure 8 shows the front panel/user interface of the monitoring and bipositional control application using the multifunction data aquisition board NI PCI-6014E.

Before starting with deploying the LabVIEW code, the following clarfications have to be made:

- the top section of the block diagram implements the data acquisition on the ai0 analog input channel, using DIFF configuration mode of the NI PCI-6014E board and generating the digital command on the 0 digital output port; It should be mentioned that the newest versions of the DAQmx drivers for National Instruments hardware components include a configuration wizard which reduces the complexity of the written code to a single block, however the configuration steps decribed at this stage remain valid.

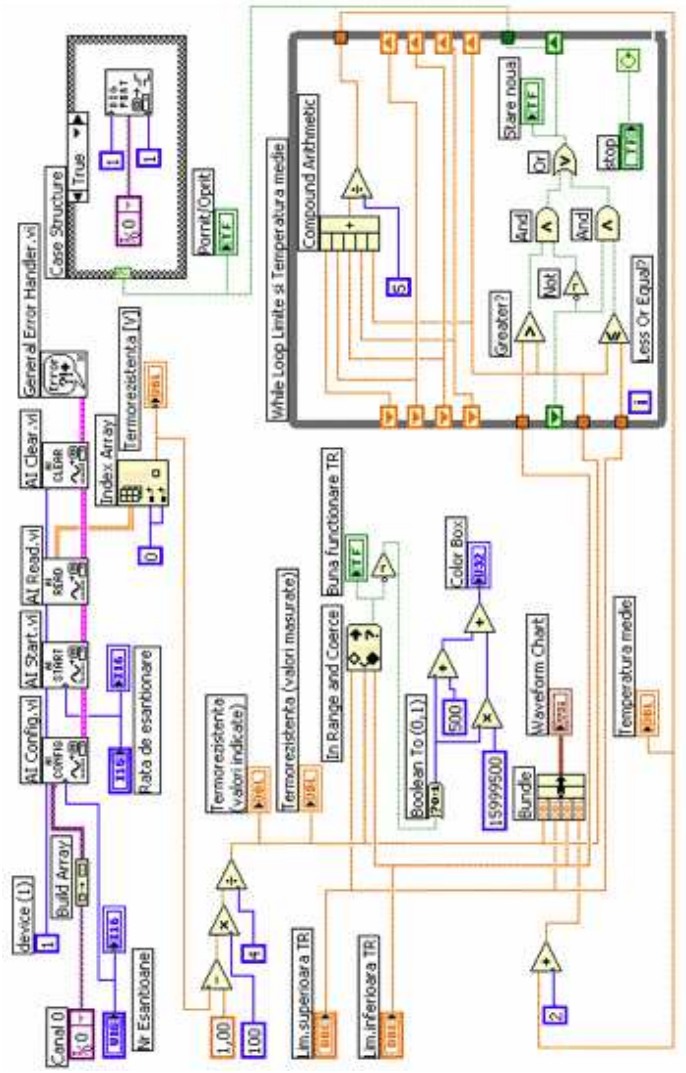

Fig. 7. Block Diagram for Temperature Monitoring and Control Application using NI PCI-6014E Board

- the acquired values represent voltage samples in the 1 ± 5 V range, considering the fact that we are measuring the voltage on a 250Ω resistance in a 4mA ÷ 20mA current loop, we show this values to the user as voltage and as degrees on the front panel;
- to better symbolize to the operator the state of the process (between or outside the lower/upper limit interval) the dedicated temeperature indicator turns blue when the temperature is between the limits and red when it is outside this interval; also when the temperature value is detected to enter the interval a LED indicator signals the good functioning of the installation;

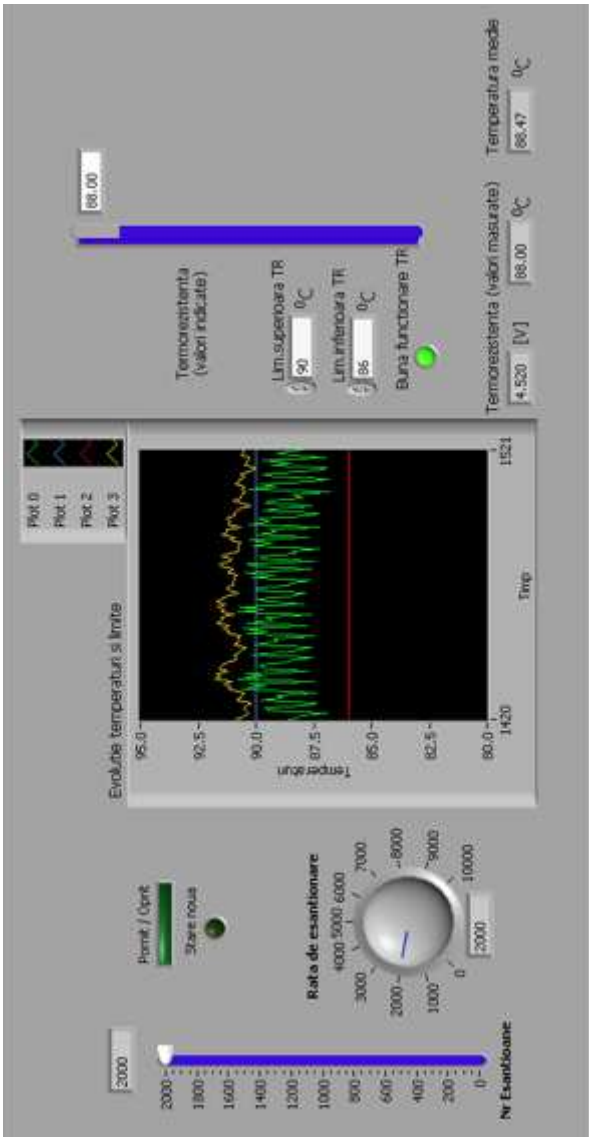

Fig. 8. Front Panel for Temperature Monitoring and Control Application using NI PCI-6014E Board

- the limits, the current temperature value and the median temperature value are illustrated on a Waveform Chart indicator; the median temperature value for the chart representation is reduced by 2 units in order not to be overwritten on the current value (the code implementing this is shown in the lower left corner of the block diagram);
- the While loop in the lower right corner of the block diagram plays a double role: it implements a logical hysteresis comparator, that means a LED indicator changes value

when the temperature value is out of the interval set by the two limits, and calculates the mean over the last 5 temperature values in a recursive way; the mean temperature indicator will offer a correct reading only after the first 5 samples have been acquired.

In order to rapidly delpoy the block diagram and the front panel the user can reffer to Figures 7 and 8 and also the LabVIEW User Manual can provide valuable references and therefore we will not go into any more details.

The virtual instrument operates when pressing the Run control on the upper toolbar and the application should be saved in the appropiate folder using a relevant name. The system operation will be described next.

After deploying the laboratory set-up according to Figure 6, with the switch K opened, the power supply SA is turned on and the heater control block is powered. We then launch the application into execution by pressing the Run continuosly button on the toolbar. Correct values for the lower and upper temperature limits should be entered on the front panel (with regard to at least a 3°C difference between the two in order to insure a smooth operation of the system) and the Waveform Chart indicator should be adapted to clearly notice the evolution of the values on the chart. The sample rate and sample number should be set to a 1:1 relation. If the Chart rate is too fast, the user should modify the Time scale of the chart.

Because, upon the first running of the application, the temperature in the thermostatic bath is low (according to the room temperature), the ON/OFF and New State LEDs will be on and the temperature color indicator will be red. Upon first reaching of the inferior temperature value, the LED indicating the good operation of the system will be switched on, the temperature indicator will become blue and the ON/OFF and New State LEDs will continue to be on. They will switch off upon reaching the upper limit.

During the operation of the application, the influence on the reaching of the upper limit with increasing temperature and on the reaching of the lower limit with decreasing temperature of the time constant of the thermoresistance will be noticed. Also, when modifiying the scale of the Y-Axis of theWaveform Chart in order to have a better view of the signals, the user will be able to quantitatively determine the acquisition noise on the analog channel and the impact of digital filtering through recursive software mediation. While running the application, the K switch should be closed and one can notice the impact of passive filtering on the analog signal. When the exepriments are over, the application is stopped using the Abort Execution control on the toolbar.

4.2 Digital signal acquisition, processing and generation

Many real-world situation present us with signals, which carry information, in a digital form. They come from physical measures with two stable states, indicating the presence/absence of the studied measure. There are also many transducers which act as detectors for the presence of the investigated measure, which supply an output signal in binary logic (absence means 0, presence means 1).

Another important category of measures commonly associated with binary signals are switches which offer two states (for example a push button closes a contact which can bring a constant voltage to a circuit, equivalent to a "1" logic state and when it is left loose the circuit is open and the corresponding state is "0"). Classic and modern automation systems often employ digital signals because many applications require mantaining the controlled parameters between certain limits and not their continuos measurement. There are also situations when the transducers generate series of impulses proportional to the investigated measure (for example, in the case of rotation speed transducers) which requires digital data

acquisition. In conclusion, the data acquisition systems are realized in such way that they allow the acquisition of binary logic voltages, compatible to the standardized voltage levels type TTL or CMOS.

Our application aims at acquiring digital TTL signals coming from a reversible counter, processing them internally in the PC and generating numeric signals which are displayed on a 7-segment display using functionality offered by the LabVIEW environment.

The laboratory set-up is described in Figure 9 which includes the following components:

- **GS**: rectangular TTL signal generator;
- **PCL**: logic circuit board which includes the counter, decoder for the 7 segments and the 7 segments display;
- **SA**: power supply 5V, 1A;
- **K**: monopolar switch for applying the TTL input to ND (direct counter) or NI (reverse counter);
- **STP-68**: external connector board, connected to the KPCI-3102 PCI Board through the 1:1 CAB-305 cable;
- **PC**: workstation with software suite installed.

The producer of the plug-in board provides appropiate drivers for the use with Windows and LabVIEW and by installing the drivers a additional user library shows up in the Functions palette of the LabVIEW interface. This allows the developers to access the specific blocks for programming application with this data acquisition board. It includes blocks such as analog input/output, digital input/output etc. We will assume that all the steps necessary for installing of the Keithley board have been followed according to the user manual provided by the manufacturer.

The first step to be taken before writing the application is the configuration of the board through the DriverLINX Configuration Panel (Start>Programs>DriverLINX). Here the user has to create a new device, Device 0, and using the configuration option setting port0 as digital input and port1 and port2 as digital outputs. The first use case is acquiring digital signals from the SN74190 reversible counter on port A (0) of the KPCI-3102.

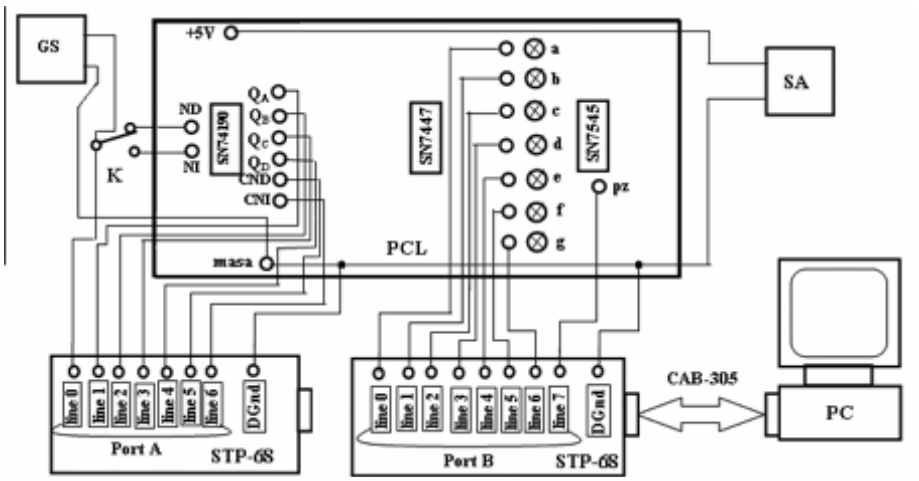

Fig. 9. Set-Up for Digital TTL Signals Acquisition, Processing and Generation using KPCI-3102 Board

Figure 10 shows the block diagram for the applicatin for direct/reverse counter and Figure 11 illustrates the front panel in the case of direct counting.

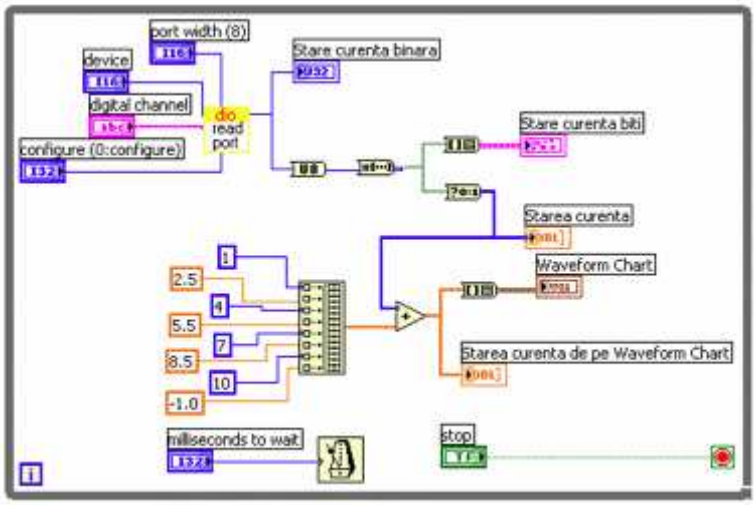

Fig. 10. Block Diagram for Direct/Reverse Counter

In order to quickly realize the front panel and block diagram, indications from the LabVIEW user manual can be used. The most important element is this case is the Keithley "dio read port" subVI which can be found in the Functions>User Libraries>Keithley DAQ VIs palette. After the correct wiring of all the elements of the block diagram, the structural integrity of the application is confirmed by the transformation of the Run indicator on the top toolbar into a continuos arrow.

Performing the experiment takes place as follows. The K switch is set in the ND position and the power supply SA and the GS TTL signal generator are turned on. After running the application the user observes 7 binary signals on the Waveform Chart of amplitude 0V and 1V, which have been modified with the constant values shown before the Build Array element in the block diagram. The signal generator frequency should be set at 10Hz and the sampling rate, modified via the milliseconds to wait control, must be chosen such as the Waveform Chart should clearly illustrate all waveforms.

Running the application will show that there is a relation between the counter input and the state of the four bistables of which the counter consists of (Qa, Qb, Qc, Qd) and the transport command CND. If K is switched, the chart will show plot 7 - CNI and plot 6 -CND will be permanently set to "1" according to the operating mode of the reversible counter NT. The application is aborted via the Stop button and can be saved under a relevant name.

In order to complete the second part of the experiment we have to realize the virtual instrument as shown in Figure 12 (block diagram) and Figure 13 (front panel).

Upon the carefull analysis of the block diagram it can be seen that it uses standard LabVIEW blocks, two subVI's built specifically by the authors (a binary counter and a 7 segment decoder) and an external control component built around the Keithley provided DAQ VI dio write port. After wiring the blocks together and placing all the elements on the front panel, the application should present no compile errors and be saved.

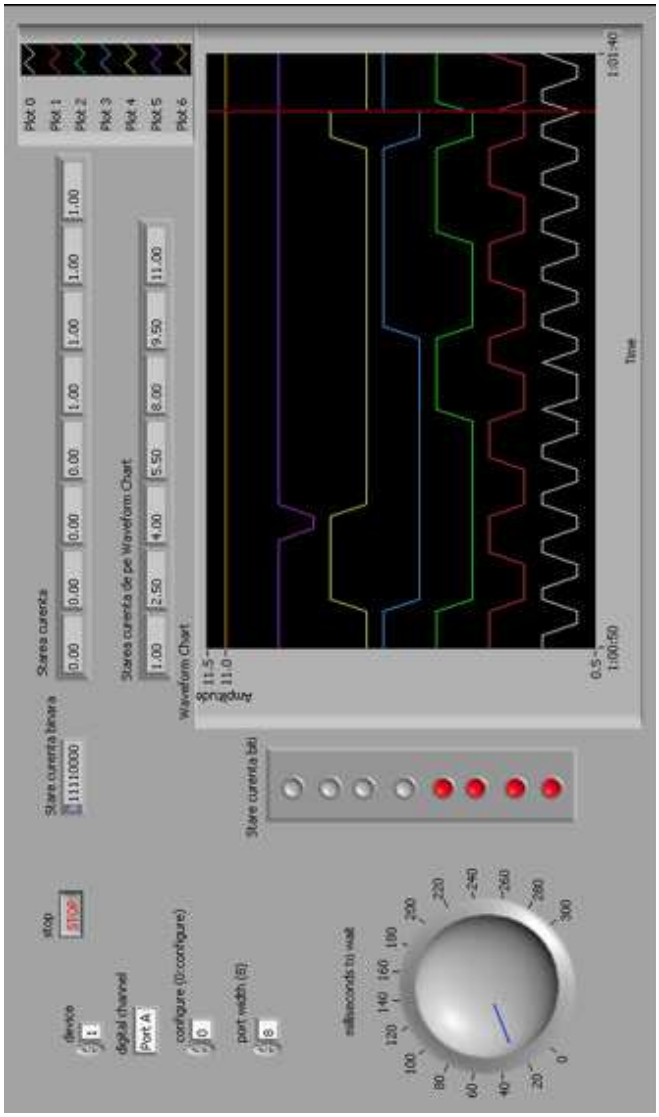

Fig. 11. Front Panel for Direct Counting Application

Having the set-up described in Figure 9, the user sets port B(1) for the digital output in the digital channel front panel control by giving it the value 1. The power supply SA is then switched on and the application is started and the single impulse operating mode is selected. The binary counter is set to 0 by pushing the boolean controls Reset and J-K in 0 and then in 1. At this moment all the 4 LEDs corresponding to the NB outputs (Qa, Qb, Qc, Qd) are inactive which represent an initial 0 stage as well as the segments of the SN7545 display. By each activation of the single impulse ("Monoimpuls") button the user can see that one binary unit is added to the counter and in the display. The coherence between the

simulated display in LabVIEW and the real 7 segment display SN7545 is checked. The switch is then moved to the Generator position with an amplitude of 8 and a frequency of around 0.0020. That will result in an automatic operation of the counter in one second increments. The Waveform Chart will show small disruptions of the waveform corresponding to the modification of the values of the NB counter. The application can be aborted by pressing the Stop button on the front panel toolbar.

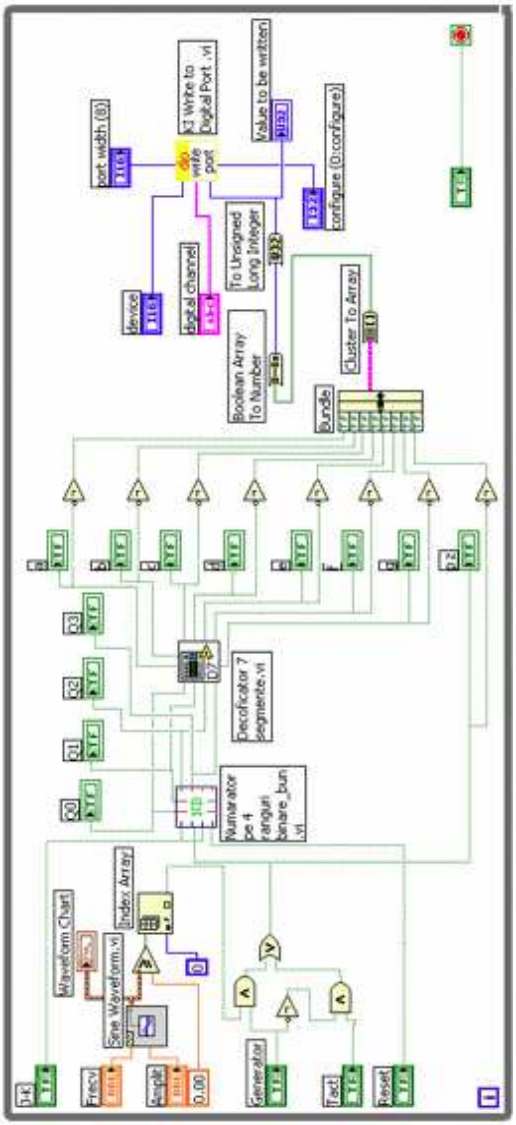

Fig. 12. Block Diagram for Controlling the Numeric Display SN7545 thorugh Port B(1) of the KPCI-3102 Board

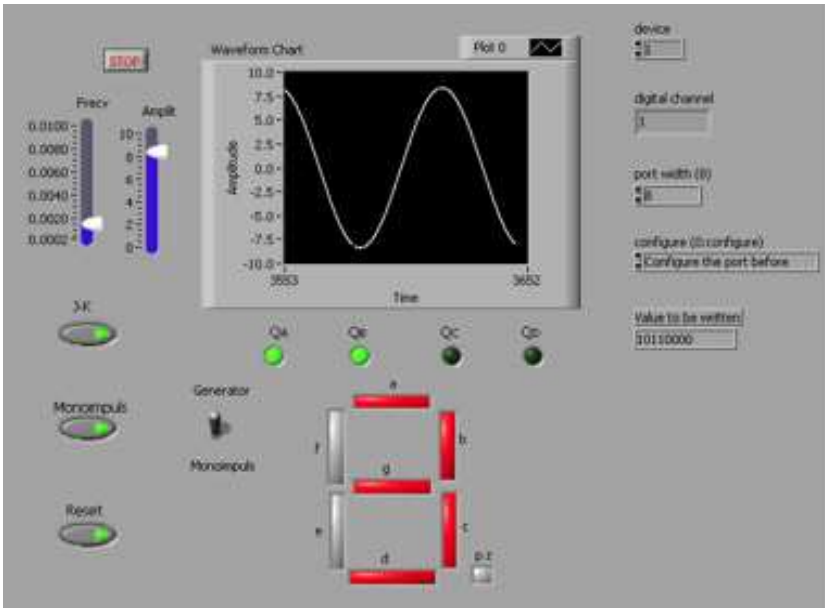

Fig. 13. Front Panel for Controlling the Numeric Display SN7545 thorugh Port B(1) of the KPCI-3102 Board

4.3 Environmental monitoring through wireless sensor network

Wireless sensor networks have represented, especially in the last decade a booming field of study and represent an interdisciplinary research area for the academic community. Although that wireless sensor networks are facing slower than expected adoption in the industry due to concerns regarding reliable communication protocols and standardization, they are a viable solution for environmental monitoring applications. In this kind of scenarios many small sized nodes should be able to provide accurate data about the investigated environmental parameters. The nodes would be powered from batteries or energy harvesting techniques and would have a lifespan ranging from months to even years.

For our experiments, we have used wireless sensor nodes produced by Memsic Inc. (former Crossbow). The experimental scenario consists of 3-4 IRIS 2.4GHz nodes deployed in the laboratory which feed data to a MIB520 USB gateway connected to the PC. The nodes consist of XM2110 radio/processing modules with MTS400 sensor boards and are battery powered from 2 x AA batteries. They are able to offer data for the following environmental parameters: temperature, humidity, pressure, light, 2-way acceleration along with health information about the network and battery voltage. The nodes run a proprietary firmware on top of TinyOS (a small scale open-source operating system for such resource constrained devices) and they form a self-organizing, self-healing wireless mesh network. MoteView and MoteConfig are the Windows applications with the help of which data is read from the gateway which finally receives all packets from the nodes and commands such as configuration information are send to the nodes.

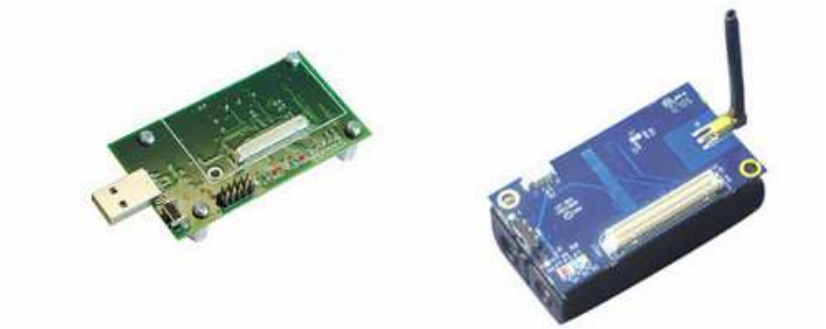

Fig. 14. MIB520 USB Gateway and IRIS Sensor Node

The application we are describing in this section is based on a LabVIEW driver developed for this wireless sensor network product by the manufacturer. This is available at ni.com as a free download and after being installed in the system it offers all the necessary subVIs which allow the developer to read data from the MIB520 USB Gateway. Our customized application with block diagram (Figure 15) and front panel (Figure 16) is shown below.

The block diagram includes elements to configure the data acquisition from the USB gateway such as COM port, data buffer size and resource access. The main while loop performs the actual read of the packets and parses them acording to the known message format for the corresponding sensor board (MTS400). Data is then available for further processing. In this case we create arrays of enivronmental measurements for the parameters mentioned above and they are linked to the shared variables which are pushed through the network, displayed and stored on the server. This application includes also a boolean shared variable which controls the data acquisition, meaning that the server operator has the possibility of remotely starting/ pausing the process. The front panel of this application is a simple representation of the list of nodes identified in the network, the parsed numeric data from the on-board sensors and simple graphical representations for two of the parameters (humidity and light).

Our main goal is to replicate and extend the functionality of the original MoteView application, this not being supported on newer operating systems such as Windows Vista or Windows 7 under the form of a stand-alone LabVIEW executable application which would enable easy distribution. This should include the virtual instrument and variable library but also the Crossbow XMesh drivers an the necessary run-time for computers without any installation of the development environment. The main functions should be database storage, custom graphs, node configuration and mapping the sensor network. The first steps have been described in this section.

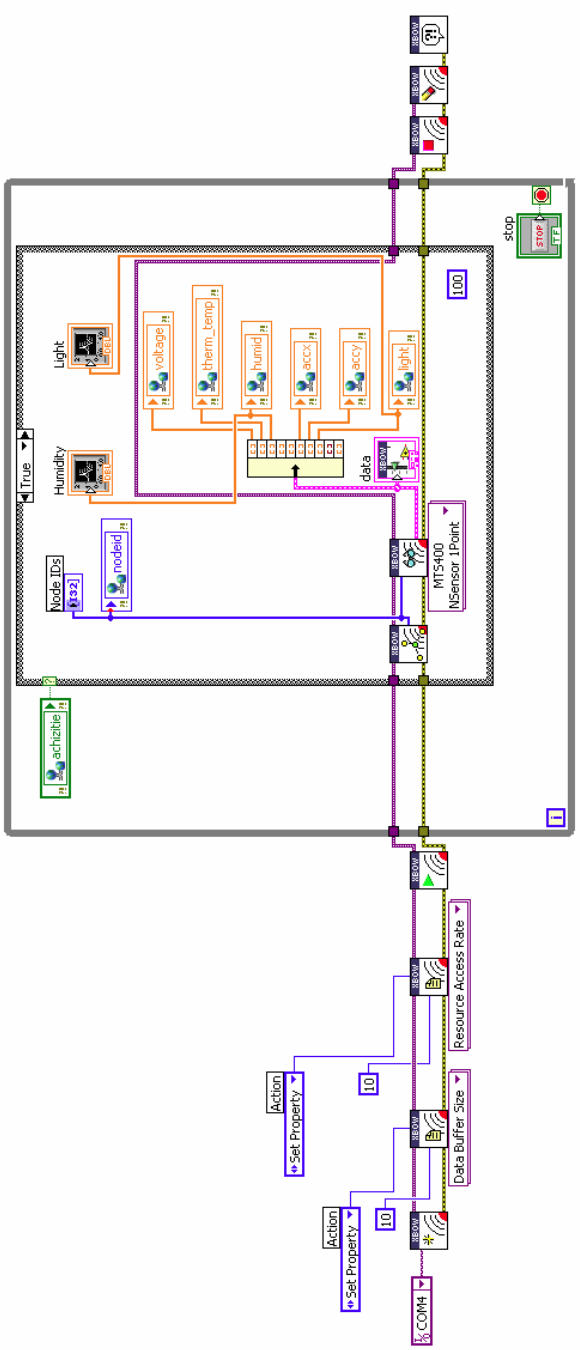

Fig. 15. Block Diagram of WSN Monitoring Application

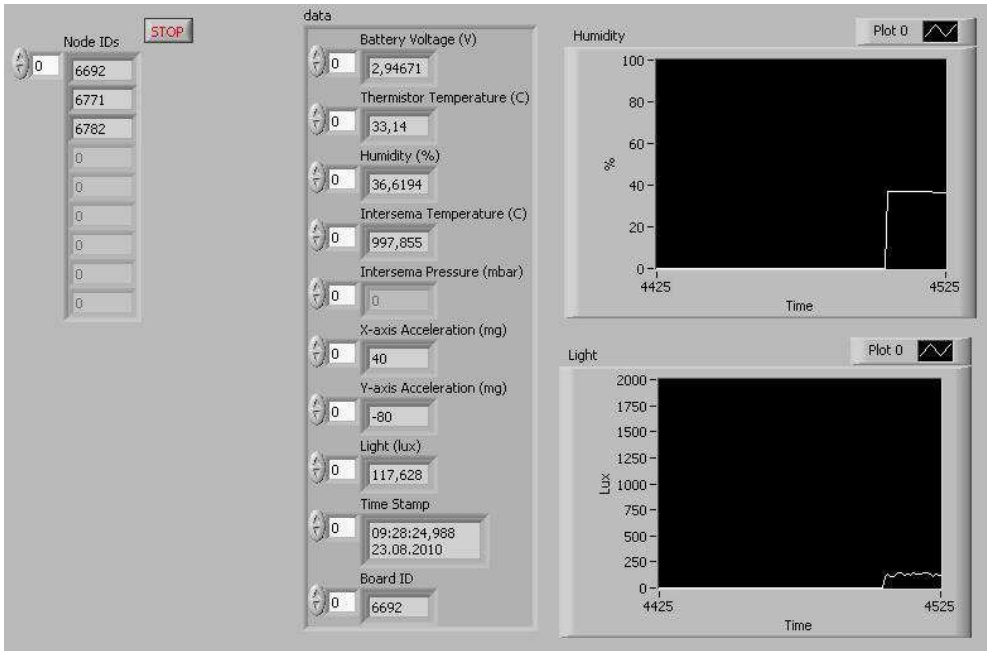

Fig. 16. Front Panel of WSN Monitoring Application

5. Server application

5.1 Communication technologies

The applications described until now in this chapter were initially designed to function as stand alone experiments on dedicated workstations. The main idea behind this chapter is to link them together under the umbrella of a single network server which collects all the data. The advantages of this distributed approach comes from the fact that the system can use dedicated workstations, each with their on specific hardware and software which are connected by a network. The server represents a more capable hardware configuration for data processing, storage and can also act as a gateway between the process and the Internet. The technology chosen to implement this concept of sharing data between tasks running on different systems is that of LabVIEW Shared Variables. The shared variables are a feature which appeared in LabVIEW since version 8 was released and have been steadily improving since. The shared variable abstracts network communication from the LabVIEW block diagram and makes it easy to share data between networked systems. The type of shared variables we are using for our deployment is networked-published shared variables of different types such as double, arrays of doubles, booleans or integers. After being added to the project library of a certain LabVIEW application, the shared variables take the form of a terminal which can be dropped onto the block diagram to be written or read from. They also offer error input and output terminals to notify the user of communication errors and a timestamp output that informs about when the value read was written. Behind all this is a custom UDP protocol to send data to a server called the shared variable engine, which then publishes the data to all clients on the network reading the shared variable. Because a

publish-subscribe architecture is used to transfer data, many clients can read and write to the same variable without writing additional code. An important feature is buffering, which can be used for accounting for temporary fluctuations between read/write rates of a variable. Readers that occasionally read a variable slower than the writer can miss some updates. If the application can tolerate missing data points occasionally, the slower read rate does not affect the application and you do not need to enable buffering. However, if the reader must receive every update, enable buffering. The SVE (Shared Variable Engine) can be hosted on Windows PCs and real time targets. In our practical experiments we found out that the custom UDP protocol needed specific ports to be opened (depeding on the implementation of the Logos architecture of LabVIEW) in order for the data to pass through the Windows firewall.
For our system the following table for shared variables was employed. The three client applications feed data into the network in the form of the shared variables. These are the read by the server which displays them on a local monitoring panel. The server also publishes its own shared variable, a boolean variable which controls the data acquisition from the wireless sensor network connected to workstation 3.

No.	Name	Type	Data	Published By
1	temp	double	Current temperature	Application 1
2	tempmed	double	Median temperature	Application 1
3	tempv	double	Acquired voltage value	Application 1
4	comanda	boolean	Digital output state	Application 1
5	limsup	double	Upper limit	Application 1
6	liminf	double	Lower limit	Application 1
7	obiectiv	boolean	Functioning between limits	Application 1
8-15	channel8_15	boolean	Digital input states	Application 2
16	nodeid	array of integer	List of detected nodes	Application 3
17	voltage	array of double	Battery voltage	Application 3
18	therm_temp	array of double	Thermistor temperatures	Application 3
19	humid	array of double	Humidity values	Application 3
20	light	array of double	Ambiental light values	Application 3
21	accx	array of double	X Axis acceleration	Application 3
22	accy	array of double	Y Axis acceleration	Application 3
23	achizitie	boolean	Start/Pause WSN monitoring	Server

Table 1. List of Shared Variables

During our experiments, the network traffic was not affected by the 23 shared variables being transmitted at high sample rates between the workstations and the server. However LabView offers several customization options in order to insure a reliable data stream between stations with very large numbers of shared variables (buffering, variable sample rate).

5.2 Description

The remote monitoring server application is made up of the block diagram and the front panel, like it can be seen in Figure 17 and Figure 18. The project for this application includes

the virtual instrumes and the library which contains references to all the shared variables being read through the network. The values are being read in a while loop which ensures continous operation fron the push of the Run button on the toolbar until the Stop button on the front panel or the Abort execution button on the toolbar have been pressed. The loop is timed at 200ms, a value which we considered insures maximum performance of the system and doesn't load the network with unnecessary samples. The shared variable read blocks are wired to the corresponding indicators in order to show the data on the front panel. The front panel represents the user interface and the most important part of this application. It is divided into three parts, each corresponding to a certain application: temperature monitoring and control, digital signal acqusition system and wireless sensor network monitoring application. The operator can view the data in near real-time, control the aqusition for the wireless sensor network through the switch button. The application can be expanded by creating a local database to store the data, generate reports and also by linking it to even more different systems. The server can also act, using the functionality provided by the LabVIEW web server as a gateway between the local network and the internet.

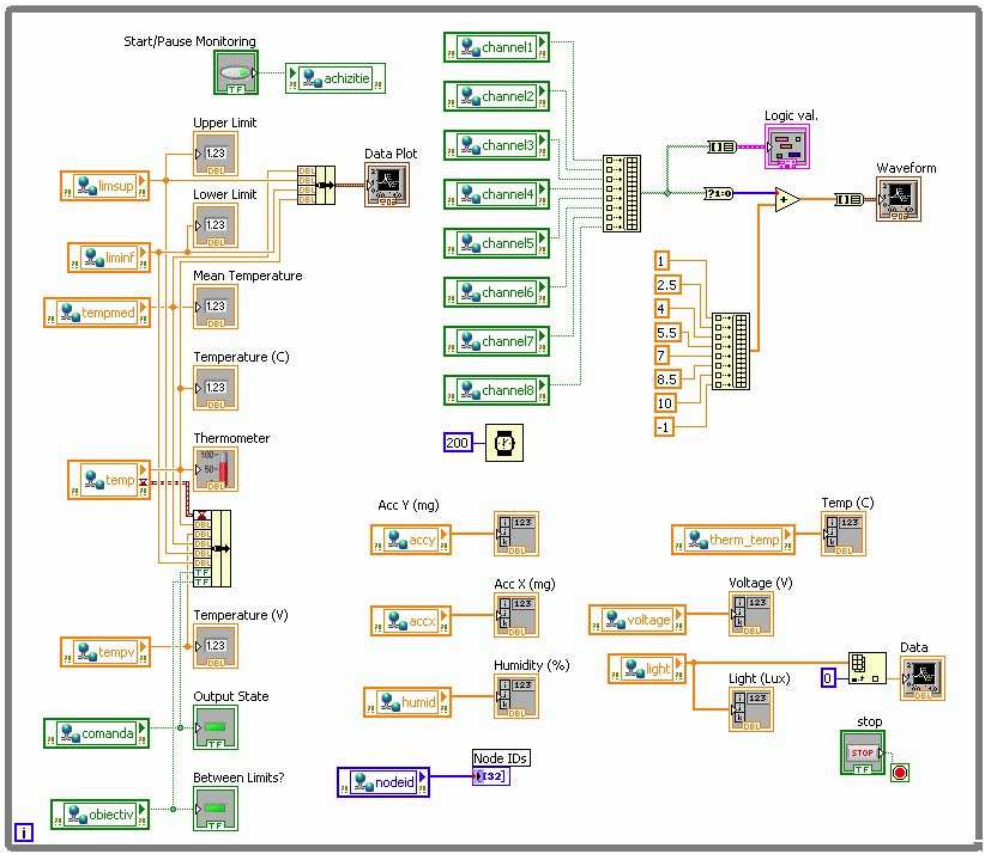

Fig. 17. Block Diagram of the Server Application

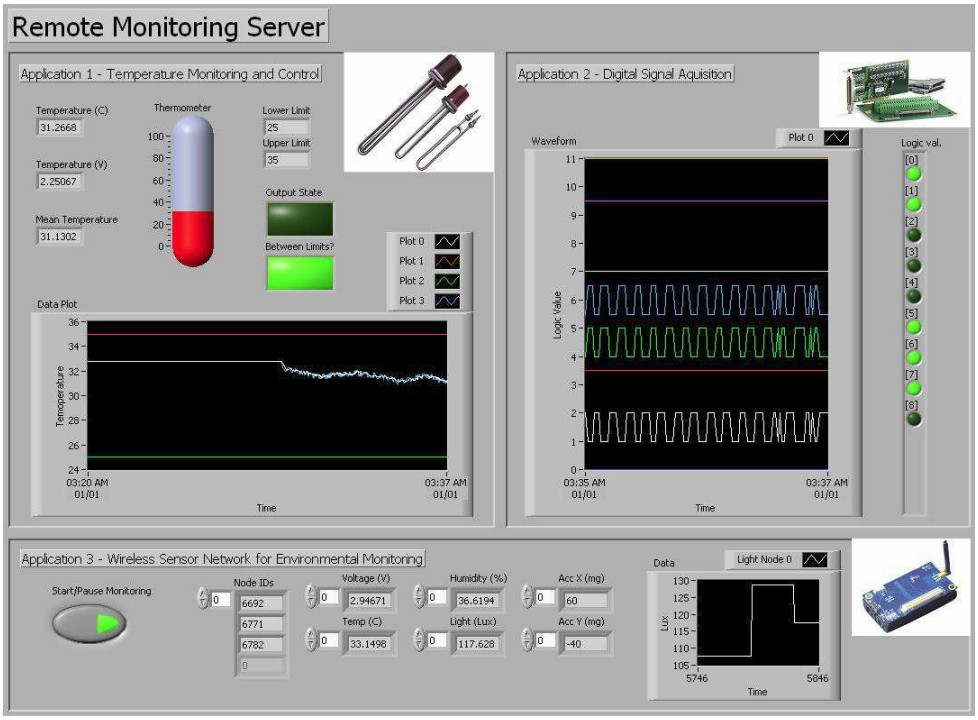

Fig. 18. Front Panel of the Server Application

6. Conclusion

The application was designed and developed to prove a couple of concepts about the data acquisition in general and some notions about the possibility of adding remote controlling/monitoring. This has a teaching purpose: it is being used for a series of experiments between several laboratories, at the moment. From one point of view one can process the experimental data gathered from a real process, but one can also see the result of one remote command sent to industrial equipment in the real time. The main part is, as we mentioned earlier, the server with the data acquisition board. The first application presented in this paper handled the process of remote controlling of the temperature of a precinct, the workstation can deal with more than one application in the same time. Thus it can monitor parameters provided by 16 sensors and it can lead till four industrial equipments in the same time, using the data acquisition board NI PCI 6014E.

The second application we have described concerns the handling of digital signals which can be found in large numbers in today's discrete automation systems. We have used a Keithley Instruments KPCI-3102 PCI board to acquire, process and generate numeric signal from/to the outside world. The integration with the LabVIEW environment has been done through appropiate drivers offered by the manufacturer which appear under the form of blocks in the instrument library, ready to be placed and wired on the block diagram.

The third application realised connectivity between the PC (with LabVIEW) and a wireless sensor network gateway. The gateway received packets from all the nodes of the network

which included environmental data from integrated sensors such as temperature, humidity, light, pressure. Our VI parsed the packets for useful data, displayed it locally and then forwarded the information to the application server.
Finally, the application server is acting like a data sink in our scenario. It receives all the process variables from the distributed system under the form of shared variables. The data is displayed, process or stored all also through LabVIEW WebServer the possibility of remote monitoring via the Internet.
Future developments will highlight the scalability of the system as we are able to add new workstations handling various processes to the network. We will focus more on reaching the communication limits of the network through a high number of shared variables with higher sample rates. The results of the experiments should give insight concerning the deployment of the LabVIEW Shared Variables for large industrial processes involving hundreds or even thousands of such network values.

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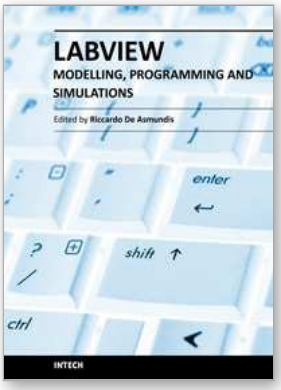

Modeling, Programming and Simulations Using LabVIEW™ Software

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Born originally as a software for instrumentation control, LabVIEW became quickly a very powerful programming language, having some characteristics which made it unique: simplicity in creating very effective User Interfaces and the G programming mode. While the former allows for the design of very professional control panels and whole applications, complete with features for distributing and installing them, the latter represents an innovative way of programming: the graphical representation of the code. The surprising aspect is that such a way of conceiving algorithms is extremely similar to the SADT method (Structured Analysis and Design Technique) introduced by Douglas T. Ross and SofTech, Inc. (USA) in 1969 from an original idea by MIT, and extensively used by the US Air Force for their projects. LabVIEW enables programming by implementing directly the equivalent of an SADT "actigram". Apart from this academic aspect, LabVIEW can be used in a variety of forms, creating projects that can spread over an enormous field of applications: from control and monitoring software to data treatment and archiving; from modeling to instrument control; from real time programming to advanced analysis tools with very powerful mathematical algorithms ready to use; from full integration with native hardware (by National Instruments) to an easy implementation of drivers for third party hardware. In this book a collection of applications covering a wide range of possibilities is presented. We go from simple or distributed control software to modeling done in LabVIEW; from very specific applications to usage in the educational environment.

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